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From: Gerry Borsuk, Conference Chair

Subject: GOMACTech 2008 Proceedings -- Distribution Clarification

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This paper explores a novel blending of the Soldier's tactical sensors with embedded sensors and systems in order to provide Soldiers and their commanders with improved situational awareness. This paper will describe this concept, discuss some of the notional information exchanges, highlight some of the technical challenges and practical aspects of this approach to small unit battle command. The views contained in this article are those of the author and should not be interpreted as representing the official views of the Department of Defense.

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Embedded Command and Control for the Soldier

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Abstract: This paper explores a novel blending of the Soldier's tactical sensors with embedded sensors and systems in order to provide Soldiers and their commanders with improved situational awareness. This paper will describe this concept, discuss some of the notional information exchanges, highlight some of the technical challenges and practical aspects of this approach to small unit battle command. The views contained in this article are those of the author and should not be interpreted as representing the official views of the Department of Defense.

Keywords: Small Unit Operations, situational awareness.

Introduction

Soldiers orient themselves to the battlefield by knowing where they are, where their buddies are, where the enemy is, and what their leader wants them to do. These basic information requirements are at the heart of many of the systems carried by today's Soldier [1].

The Soldier and the leader need a common understanding of these elements for successful mission accomplishment. Most material solutions to achieving these objectives assume a conventional communications system, reliant on transmission of information via imagery, data, or voice.

A basic Soldier function after orienting themselves to the battlefield is to engage the enemy, and this often requires positively identifying the enemy, and aiming and firing a weapon system, such as an M4A1 carbine or M16.

Consider the Multiple Integrated Laser Engagement System (MILES 2000). It is an integrated training system, and consists of transmitter and receiver systems integrated into familiar components – small arms, helmets, vests, and vehicles[3]. The system transmits coded light sequences that are interpreted as weapons engagements and calculates damage effects (hit, kill, near-miss) in real time. The vests have the ability to incorporate GPS and data link interface to the combat training center. MILES provides a realistic representation of weapons performance and weapons effects – including ranges and lethalities. It is robust under field conditions and provides rapid feedback, data for real time and after action analysis.

The MILES system allows soldiers to train – with few training artificialities. The local sensor suites embedded in the soldier weapon system are critical to the efficient system operation - they are the communications backbone for the training system, and after initialization, the essential operator actions are to aim and fire. Individual and system performance data is aggregated and a "picture" emerges of the overall effectiveness of the training – and the units in training. .

It also provides a proxy for the Soldier's sense of the battlefield – but does not provide sufficient information to know more about the tactical situation.

Information exchanges are typically associated with movement, and offensive, defensive and security operations [4]. Common reports include position reports, contact reports, spot reports and status reports, informing higher echelons of conditions and status. Command information exchanges follow similar functions and include mission, enemy terrain and weather, troops available and time (METT-T). These exchanges are usually structured into standard formats with the information being presented in a prescribed sequence.

Small units have and use several communication options for information exchange between soldiers including hand signals, audible (voice or sound) signals, and optical or radio signals. Non-verbal information exchanges tend to be situation dependent (hand and arm signals), and provide highly specific direction or status.

The U.S. Army's Land Warrior System represents an advanced approach to sharing this information on the battlefield (specification values were obtained from open sources for this paper and are considered representative). For example, as a first spiral of the Land Warrior System, the Army developed and is fielding the Commander's Digital Assistant to provide situational awareness, access to tactical and intelligence data at company and platoon levels and voice and data connectivity between users [3]. The Land Warrior System has undergone extensive development and is being deployed in an interim configuration.

Concept

Consider that Soldiers use broad gestures (hand and arm signals) or small radios to communicate locally, and that these gestures and the Soldier's posture (upright, crouching, prone), and weapon status and condition (armed or safe, pointing direction, trigger pull, recoil and flash) in the aggregate provide an intuitive representation of the Soldier's sense of the environment – from relaxed (weapon safe and stowed) to alert (weapon safe or armed and in a carry position) to engaged (crouched, weapon armed and firing in a direction).

For example, with these few inputs, enemy contact might be indicated by weapons status, weapon position and action (for example armed, near helmet, trigger pull, recoil, flash).

Now imagine a MILES-like system which *relays* these conditions to a central node. This central node aggregates the inputs from the individual Soldiers (sensors), forms a fused assessment of the environment near the soldiers, and relays a geographically referenced report to commanders.

A number of useful conditions would be available to the commander *without* a voice, data or imagery report from the unit:

- I am at (location) (time);
- my weapons are/are not in use
- if my weapons are not in use, they are in a non-threatening (safe/pointed down), alert (safe/carry), ready(arm/carry), or in danger (armed/ weapon boresight near helmet) status;
- if my weapons are in use, they are directing fire in this direction, and I have expended xxx rounds.

If soldier actions, gestures and weapons movements can provide information about the Soldier's assessment of the current environment and tactical situation, then consider the effect of aggregating individual soldier assessments.

Soldiers operate in teams or squads, and these operate as a coherent unit, and as part of a platoon or other larger unit. If the majority of a given squad's members assumed defensive postures (prone, crouch, kneel), and were aiming and firing weapons, it would be reasonable to assume that unit was in contact with an enemy. An assessment of the condition of the supported and supporting units would provide an *aggregated situational and spatial assessment of the local conditions as sensed by the Soldiers*.

Transmission of weapons firing rates would be an estimate of contact intensity, and could provide commanders with an estimate of enemy location, and own unit support status and support requirements, allowing Soldiers to focus "down range". False positives and false negatives could be reduced by the concurrent voting action of sensors associated with individual unit members. Scaling up the unit size provides both robustness and a sense of the magnitude and complexity of the situation.

These elements could be composed to form a contact report or situation report and forwarded to commanders *without* requiring other actions by the Soldiers.

Technical Challenges

Energy

The Land Warrior System requires 12-72 hours of runtime using a disposable energy source weighing less than 2 pounds [4].

The Land Warrior System power needs are dominated by communications, computing, Soldier interface and optical sensor loads. Intelligent system use by the Soldier, use of advanced power management technology, and low power design approaches reduce the system load to about 20 watts.

Table 1 summarizes size weight and power capabilities if representative commercial technologies were used to accomplish some of the functions performed by the Land Warrior System.

Table 1. Example size weight and power for functional tasks

		size	wt	pwr	time
Where am I	GPS	20 in3	0.6 lbs	<0.1w	>14 hrs
Where are buddies	Pocket PC	12 in3	0.4 lbs	<1w	>14 hrs
Where is enemy	PVS-22	49 in3	1.9 lbs	<0.1w	40 hrs
	ACOG	41 in3	1.0 lbs	none	NA
Command Intent	MBIT R	34 in3	1.9 lbs	5.3w	>10 hrs
totals		156in3	5.8 lbs	6.5w	>10 hrs

The system power and energy requirements are dominated by communications systems. A standard military battery such as a BA5590 stores 180 watt hours and weighs 2.25 pounds [5]. A future system would require an average system power requirement of less than 2 watts to allow powering from a single BA5590 for 100 hours of runtime.

Commercially derived Personal Area Networks (PANs) using IEEE 802.15.4 standards or equivalent could be used to provide low power networking at less than 1 watt average power (typical reduced function devices operate at powers of less than 100 milliwatts) [6]. Reducing communications power requirements below 0.5 watts would allow a BA 5590 battery to power the entire system for over 20 hours.

Baseline weapon and sensor requirements

Critical to rapid introduction and fielding would be the re-use of existing systems. The M4A1 carbine would be a typical baseline weapon.

Potential optical sensor systems would require day and night time capability. Baseline Land Warrior weapon and sensor systems include a Daylight Video Scope (DVS) (1.5-6x), and an 8-12 micron Thermal Weapon Sight (TWS) fitted on an M4A1 carbine.

Table 3 summarizes some performance and power requirements for commercially available sensors. In general, higher performance sensors are to the left, as are the higher power sensors. Significant effort will be required to reduce the required power and achieve the desired performance.

Table 3. Potential Optical Sensors

	InGaAs	Ge	GaAs	CMOS
Spectral response (nm)	400-1700	400-1650	450-900	450-850
format	640 x 512	744 x 576	Gen3 >60lp/mm	640 x 480 color
cooling	no	yes	no	no
Power(w)	<7	<5	<0.2	<1.5

Baseline system sensor requirements would derive from planned and fielded optical systems. Current night vision devices such at the AN/PVS-22 Universal Night Scope could provide night vision capability, and daytime capability could be provided by the Advanced Combat Optical Gunsight (ACOG). Such a sensor system would have reasonable performance, at a low power, but would weigh in at over 3 pounds.

Weight

System weights are dominated by the weapon and helmet system. Body armor is a significant weight but is excluded from the electronics and sensor weight totals. Communications and computing weights are relatively low, if energy sources such as batteries are accounted for separately.

An M4A1 carbine weighs about 6.6 pounds loaded, adding a PVS-22 and ACOG increases weapon weight by over 3 pounds, and approximates the weight of the Land Warrior Weapon System. Additional sensors would have to be added to the weapon to include MILES 2000-like small arms sensors (flash detection and acceleration), small beacons to estimate weapon orientation and network to the control device. Addition of illumination, bayonet clips and sensors will increase the overall weapon system weight.

Table 2 summarizes some alternative weapons and weights.

Table 2. Alternative weapon weights

	M16	**M4A1**	**XM-8**	**C15/97**
Weight (lbs)	7.5	6.6	5.9	4.0

A significant technical challenge exists to reduce the combined weapon/ sensor weight; one approach would be to use or develop a lightweight weapon; an alternative would be to develop a lightweight combined day/night optical system.

It will be important to have both low power (reduce energy source requirements, reducing weight) and low weight (reducing overall weight) for the sensor system..

Network Architecture

The sensor Physical Layer would be a body area PAN connected through an 802.15. series standard to an existing gateway system. IEEE 802.15.4 standard is used for comparison purposes.

Use of IEEE 802.15.4 standards would restrict RF communications to three ISM bands. The 2.4 GHz band is generally available worldwide and has numerous high performance low power transmitter and receiver systems available.

The individual sensor nodes would form a PAN. on the soldier. These would link to a Full Function Device (node) on the Soldier, which would aggregate RFD inputs into a message.

Soldiers in small unit operations typically stay within covering small arms weapons ranges, resulting in communications ranges generally exceeding IEEE 802.15 capabilities at the extremes of dispersion. A mesh networking protocol for data exchange and forwarding, and a personal role radio for voice network communications at longer ranges would be a reasonable compromise.
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Practical gateways exist today. The Marine Corps, for example, has developed the Portable Forward Entry Device (PFED) and the Dismounted Data Acquisition Terminal (D-DACT). Such devices would act as the gateway interface to higher command and control systems, such as the Command and Control Portable Computer (C2PC). In a similar fashion, the system would interface with the Army Battle Command System at the Company level.

Irrespective of the gateway, the aggregated information should be in an existing message format, such as MIL-STD 188-220. Signals officers would have to set policies to ensure that information flowed to the correct users.

In order to meet interoperability standards, the system would require software translation and emulation.

Security

At the sensor level, existing commercial encryption standards, such as those available in IEEE 802.15.4 would be used to link sensor nodes together. PKI encryption would be used to encrypt PAN information relayed to the gateway linkage to existing communications systems. Virus protection, firewalls and a physical security protocol would be required to prevent compromised systems from affecting higher echelon command and control systems. Additionally, the policies and algorithms used for data aggregation can be used to reduce the severity of compromise of one to several units.

The challenge of compromised systems is significant and should not be minimized. Additionally, the ability of a Soldier to use a faulty or un-sensored weapon and still provide information to the network needs to be included in an overall system design

Human computer interface

The concept of gesture based interfaces is well-established. The Nintendo Wii ™ is a popular commercial game system and has a gesture-based interface. Players use hand, arm and body accelerations as sensed by a small controller to control game action.

Fully realizing a gesture-based or gesture-dominated communications system requires developing a vocabulary of non-verbal gestures, postures and signals used by Soldiers, translating these into reliable state estimates of the Soldier's situational awareness assessment, and training the system to understand the gestures of the individual Soldier.

System control requirements could be handled by the sensor network using gesture-based controls and weapons status as the interface. Subtle gestures, not recognizable by observers as control or communications signals could be available to the Soldier.

Display of information such as maps could be either by helmet mounted display, a separate display, or via the optical sensor display. An audio input/output device with a voice operated interface could be used for text message readout or composition.

Conclusions

This paper presented a novel blending of the Soldier's tactical sensors with embedded sensors and systems in order to provide Soldiers and their commanders with improved situational awareness. The system concept was presented, along with discussions of key technical and developmental issues.

Significant technical challenges must be overcome in order to successfully demonstrate this concept, including

- Order of magnitude reduction in communication and sensor power demand
- System level weight control and reduction
- System human computer interface development
- Sensor data aggregation, and
- System level security and interfaces to minimize required modifications to existing systems.

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If implemented, such a system could provide Soldiers and their commanders with improved situational awareness using a novel sensor interface – where *the Soldier is the Sensor* [7].

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